

EXPERIMENTER'S WORKSHOP

TWEAK, TUNE, AND MODIFY!

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All-Purpose Op-Amps

A new Windows 95/98/NT program and the Commtronics Engineering CE-232 Scanner/Computer Interface¹ instigated this month's op-amp circuit.

For years, the CE-232 — an interface for the PRO-2004, PRO-2005, and PRO-2006 and selected other scanners — was controlled by a DOS program that comes with the interface. However, one major feature of the CE-232 was unsupported by the software: eight channels of 8-bit Analog-to-Digital (A/D) converters! Early this year, I mentioned the feature to Windows developer, Paul Turton, who romped to the challenge with *Pro-Turbo* for the CE-232.

*Pro-Turbo*² does everything the old MS-DOS program did and much more, including full support for those eight mysterious A/D converters.

Analog-to-Digital Converters?

The beauty of computers interfaced with radios is this: If an A/D can convert an analog signal to digital code, then a computer can read, process, and store the information. The CE-232's eight 8-bit A/D converters are perfect for receiving all kinds of analog information from the radio; and the *Pro-Turbo* software is perfect for processing the data and making sure the computer stores it in an intelligible manner.

The point is, you can't stick just any analog signal into the input of an A/D. You could blow it up, and A/Ds aren't cheap. A simple technique called signal conditioning is required, not only for the safety of the A/D, but also for the accuracy of the data. Well, when Paul Turton liberated those awesome A/D converters in the CE-232, I had to figure out the signal conditioning requirements. I had two powerful applications in mind: S-metering and frequency measurement of incoming signals!

The Concept

Suppose there are ten transmitters on a frequency; it's pretty hard to tell them apart, even with the logging function that comes with most interface software nowadays. However, if not only the signal hits are logged, but the relative signal strengths and precision frequency offsets as well, then you've got "thumbprints" that can be used to differenti-

ate the signals. Chances are that no two transmitters will arrive at your location with exactly the same signal strength; and chances are that no two will be on exactly the same frequency.

The PRO-2004/5/6 and certain other scanners have an internal circuit in which the voltage can indicate even minor frequency offsets from the tuning of the receiver. My old "Center Tune Meter" modification (MOD-27) used LEDs to show frequency offsets in 1250 Hz increments, but an A/D converter can resolve offsets down to less than 100 Hz! (8-bits = $2^8 = 256$ points of measure; so 256 points across 20 kHz of intermediate frequency [IF] bandwidth is 78 Hz per point!)

Signal Conditioning

My old MOD-25 S-meter circuit taps and demodulates the receiver's third IF for a DC output of about 0.8V to indicate relative signal strengths. These two tools are pretty cool for the avid radioist, but the computer age left them wallowing in the dust since analog and digital don't usually mix very well.

The output of my S-Meter circuit is about 0.8V, directly proportional to signal strength. The "center-tune" function of the scanner has a range of about 7V to 1.5V, inversely proportional to the frequency offset over a range of +/- 10 kHz.

This poses two distinctly different problems. The S-meter's 0.8V is pretty weak and uses only about 16% of the resolution capabilities of a 5V A/D. The second problem has two issues, chief of which is that a 7V input will blow a 5V A/D to kingdom-come. Then there is that inverse relationship where 7V represents about -10 kHz of center and 1.4V is +10 kHz of center.

Proper signal conditioning protects expensive devices, gets the most out of an application, and

helps give an accurate result. Fortunately, it's relatively easy with the modern op-amp (operational amplifier) chip. Add a few resistors and capacitors, and maybe a calibration potentiometer, and you're all set — and that's the topic of the rest of this article. Though *Pro-Turbo* and the CE-232 Interface provided the original impetus, op-amps have hundreds of uses around shop and shack.

Op-Amps for the Experimenter

Figure 1 is the schematic diagram, using the LM-324, a quad analog op-amp. My circuit uses two of the four sections, so there are two spare channels for future projects. You can build one channel of the circuit independently of the other if you want. That is, the upper half from the ground line up is one circuit, quite independent of the second channel starting with the ground line and down.

Channel 1 is a non-inverting amplifier, the gain of which is fixed by the combination of R2 and R3. The formula is shown in Figure 1, should you want to experiment with it. Channel 2 is an inverting amplifier (or attenuator). The difference between the two is not of polarity — rather, of direction — so don't get confused.

A non-inverting function maintains the

FIG-1: MULTI-PURPOSE OP-AMPS

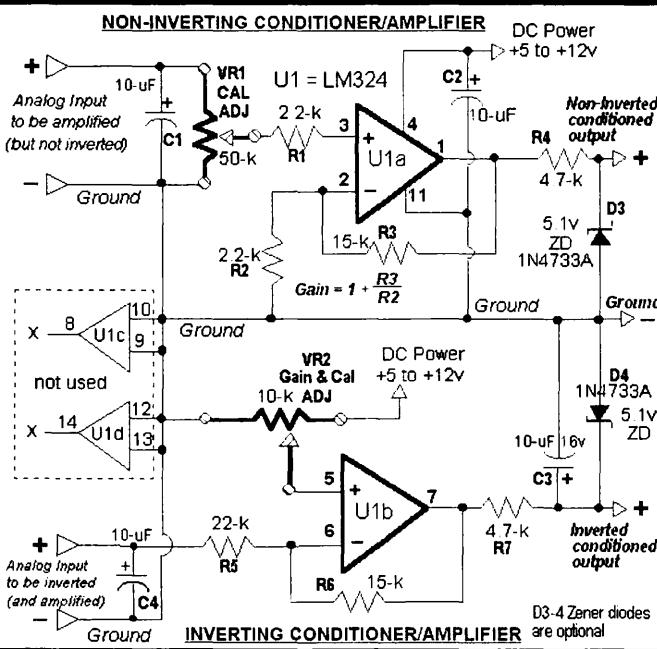
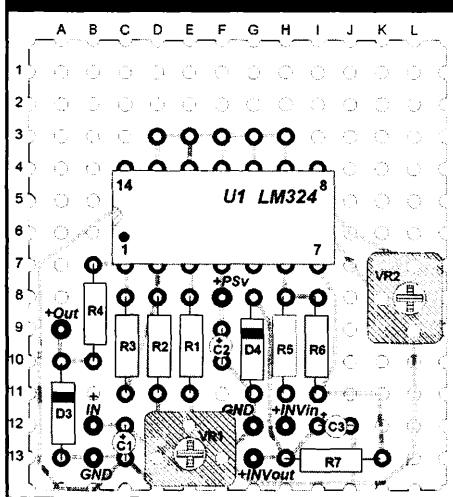


FIG-2: COMPONENT SIDE

slope of the input signal. That is, an input changing from 0.1V to 0.2V into a gain of 10 will be outputted as 1V rising to 2V. An inverting function would output 2V decreasing to 1V, you see. In all cases, the polarity of the signal remains positive (+) with respect to ground.

Figures 2 and 3 show how to build the op-amp signal conditioner on a piece of perfboard. Follow those "maps" and you won't run into trouble.

■ Applications

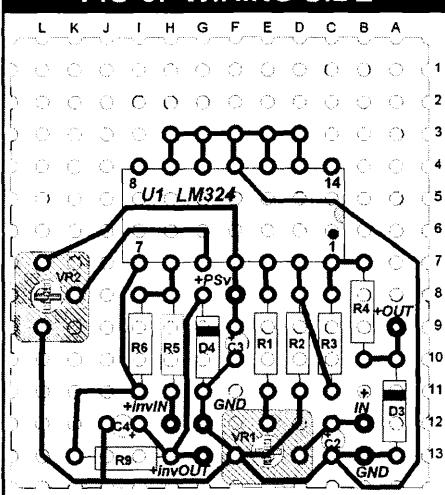
Channel 1 of the op-amp is for moderate amplification without inverting the signal. It's ideal for an S-meter circuit that puts out maybe 0-0.7V, give or take. As shown, the Ch-1 op-amp will output a more useful 0-5V S-metering signal; good for driving an analog meter, an LED bargraph meter, or even a DVM for excellent resolution of minor differences of signal strength. Of course, it's ideal for a 5V A/D converter, too! <grin>

Channel 2 inverts the signal direction and has a mild attenuation factor to limit the output swing to 5V. I designed it for that "center-tune" signal in the PRO-2004/5/6 and PRO-2035/2042 scanners available at IC-2, Pin 9, where the signal varies from about 1V to 7V, inversely proportional to frequency offsets. My mind thinks in direct proportion, for one thing, and two, I didn't want to blow up my A/D converter.

So, the two channels are good examples to cut your teeth on analog op-amps, and they're not limited to A/D and computer applications, either.

■ Calibrations

The gain (amplification factor) of U1a in Fig-1 is fixed by R2 and R3. You can change one or both values for

FIG-3: WIRING SIDE

any desired reasonable gain. VR1 is provided, not so much as a gain-adjust; rather it is a calibration adjustment to match whatever signal range you feed into Ch-1 to the fixed gain of the amplifier. Say you have an analog signal of 0-2V and you want an output of 0 to 5V. You might choose a 20-k resistor for R3 and a 10-k resistor for R2 to yield a gain of 3. (1+ 20/10) Then you'd adjust VR1 for a max input of 1.667V to Pin 3 of U1a to get the desired 5V output (1.667 x 3 = 5.0)

The gain of U1b is established largely by R5 and R6, and VR2 is a calibration adjustment that sets the maximum output of U1b to let you match a precise output to a known input.

■ Suggestions/Recommendations

1. Use a DC power supply that's at least 2 volts greater than the maximum desired outputs of U1. An 8V supply is perfect for 5V outputs, but you can use 12V, too. DC power isn't critical, but it should be regulated and well filtered.
2. Build this circuit on perfboard as shown and use it as a learning-aid before conjuring up your needs and applications. You need one or two voltmeters and the Analog Signal Emulator shown in Figure 4. Connect a power supply as shown in Fig-5 and connect a voltmeter to the "Variable

Analog Output." Adjust the potentiometer for a desired output as seen on the meter. Then connect the voltmeter to the outputs of U1 as shown in Fig-1; connect the Analog Emulator "Variable Analog Output" to one of the inputs to the op-amp.

Then slightly adjust the Emulator's potentiometer while watching the output of the op-amp on the voltmeter. It helps to have two voltmeters, one measuring the input and the other at the output of the op-amp so that you can see the effects on the output as the input changes. Believe me, you'll learn a lot about op-amps in a short time if you take this extra time and trouble at first.

3. The inputs of unused channels of the op-amp must be grounded, as shown in Fig-1.
4. Zener diodes D3 and D4 are optional. I used them to limit the outputs to 5.1V so that my A/D converters wouldn't blow up if the input limits were exceeded. If you're not feeding an A/D, then D3-4 probably aren't needed or desired.

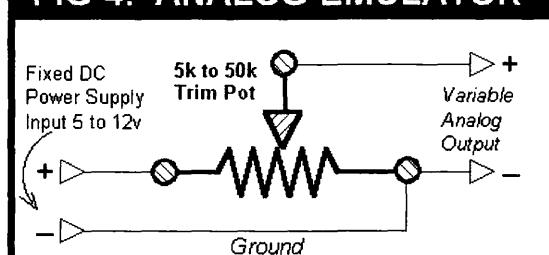
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■ Footnotes

1. I am not affiliated with Pro-Turbo, though I am a designer and the supplier of the CE-232. For more information on the CE-232, contact me by e-mail, fax, or snail mail to the addresses at the end of this article, or see my latest book, *The Ultimate Scanner* (Cheek³), for plans on "rolling your own."
2. You can get more information about Pro-Turbo and even download a demo version from: <http://www.iaw.on.ca/~jabba/pro-turbo.htm> or send e-mail to: ptturton@iaw.on.ca or jabba@iaw.on.ca

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FIG-4: ANALOG EMULATOR

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